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ABSTRACT

The use of interactive computer graphics for individualized and classroom instruction in Engineering at the University of Texas is described in this document. Two modes of instruction are discussed: (1) student individualized instruction at the terminal, and (2) classroom (group) instruction by a lecturer using time-sharing techniques. The use of a proposed device called a real-time, plotter-projector for group display is discussed, together with data on its cost and the cost effectiveness of the equipment for classroom and laboratory instruction. A list of the equipment needed for a classroom, and a photograph of the plotter-projector is included. (Author/DS)

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A NEW DIMENSION IN CLASSROOM EDUCATION

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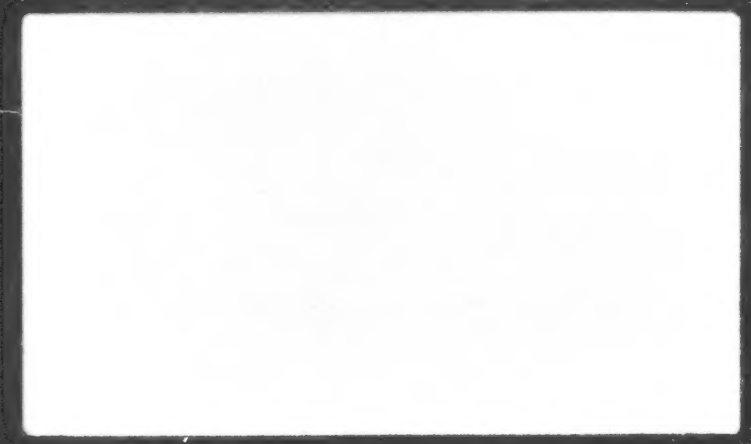

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ABSTRACT

This paper describes the use of interactive computer graphics for both individualized and classroom instruction in engineering at The University of Texas at Austin. Two modes of instruction are discussed: (1) student individualized instruction at the terminal; and (2) classroom (group) instruction by the lecturer using time-sharing techniques. The use of a unique device for group display (called a real-time plotter/projector) is discussed, together with data on costs and the cost effectiveness of the equipment for classroom and laboratory instruction.

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Introduction

Visual aids can make a distinct contribution to learning effectiveness in any type of classroom atmosphere, whether lecture, recitation, or PSI (Personalized System of Instruction). Until a few years ago, educational technology was limited to such devices as film strips, transparency projection, movies, and charts, plus the time-tested blackboard and chalk. In spite of the increasing impact of the digital computer in the undergraduate and graduate curriculum, ways of using the digital computer directly in the classroom to supplement, and perhaps replace, other modes of visual instruction to date have been quite limited. This article provides answers to two important questions, namely:

(1) How can computers be used in the classroom as visual aids within the context of severe capital and budgetary limitations?

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(2) What educational advantages, or disadvantages, are there in such devices as teaching tools?

We describe here a proposed computer-based teaching tool that can be used to illustrate graphical material prepared directly by the computer. It can be used to illustrate lectures, to pose questions to students such as would develop in recitations or discussions, and can also be used in a tutorial mode to give the student information, and react to his responses. The device to be described is a coupled teletype plotter-projector, or more specifically a combination of an overhead projector with an X-Y plotter and teletype. The plotter-projector was developed as part of Project C-BE at The University of Texas at Austin funded by the National Science Foundation. Project C-BE provides (through time-sharing computing and interactive graphics) the means to simulate dynamic processes and to represent laboratory or field experience in the classroom.

Role of the Projector-Plotter in Group Teaching

The major problem that an instructor in engineering faces in teaching students both the theory and practice pertinent to real world processes is providing the students with a thorough understanding of the concepts involved. This problem can be overcome to a large degree by using digital computer simulation techniques to model engineering processes. Recent advances in the field of interactive graphic displays to simulate on-line real time processes have added a new dimension in the field of educational

technology that has yet to be thoroughly exploited. Time-sharing facilities combined with appropriate graphic displays now make it possible to provide the student with the illusion of an "on-line real time plant" merely by employing the use of simulation techniques. An instructor's teaching effectiveness can be considerably enhanced when the devices involved (computer teleprinters, X-Y analog plotters, and data sets) can be located away from a central processor in the classroom through a time-sharing network.

The remotely located projector-plotter can serve a number of purposes in its role as a visual aid in the classroom. First, it can be used to give graphic demonstrations of the dynamic operation of simulated processes. Although the same type of demonstrations can be provided by movies and tapes, it is clear that the plotter-computer arrangement can be completely flexible insofar as the scope and content of the problems illustrated, whereas movies or tapes must follow a fixed format. Consequently, it would be impossible to answer student questions about changes in the parameters, initial conditions, boundary conditions, or other aspects of the model with the usual types of visual aids. Of course, it is not yet possible to present graphical results in five colors, with titles and different perspectives, but these are perhaps too much to hope for at the present time.

A second use of the projection-plotter combination is in questioning students as to their understanding of the material that is being discussed. The instructor can set up a variation of what he has been describing to the class and ask various students to answer questions concerning the outcome

engendered by these changes. He can then demonstrate immediately whether or not the response of the student is appropriate and proceed from the correct (or incorrect) response to additional questions.

One of the best features of the plotter-projector combination is that it generates student interest because the student can interact with the instructor directly. Also, because the instructor is not handicapped by carrying out long calculations or remembering some distant page in a text, he can ask much more challenging questions, and the student can feel that his input into the class is really worthwhile.

A fourth role of the projector-plotter is for students to demonstrate in front of the class their proficiency in solving homework problems. Instead of writing equations on the board, the student can call upon the computer to illustrate his homework results.

Finally, the plotter-projector combination can be used to provide questions for examinations and tests in class. The instructor can operate the simulated process to a certain degree and then request that the student explain what has happened or explain what he will expect to see happen with subsequent operation.

Certainly the projector-plotter combination facilitates learning via student interaction with the instructor and the visual aids. It also has an advantage in that it provides short learning episodes and repetitive practice so that the behavioral objectives of the course are achieved most effectively.

Equipment Configuration

During the initial phase of the project the equipment configuration consisted of the least expensive terminal and plotter equipment that was available at the time, namely:

One Model ASR-33 Teletypewriter	$ 958.00
One Time Share Peripherals Corp. Model TSP-212	$3,500.00
One Omnitec Corporation Model 701A Acoustic Coupler	$ 300.00
TOTAL:	$4,758.00

After a semester's operation with the above equipment, some changes were deemed necessary because the plotting and printing rates were too slow to maintain a high level of student interest while operating at the 10 character per second speed. In order to overcome this problem a 30 character per second impact teleprinter was purchased (a DiAn Model 9030 wide carriage terminal), and the X-Y plotter was modified for 30 character per second operation, which improved the efficiency of the entire operation. Costs for the improved configuration of equipment shown in Figure 1, excluding the tape recorder, were:

One DiAn Corp. Model 9030 Terminal	$3,100.00
One Time Share Peripherals Corp. Model TSP-212-30	$3,700.00
One Omnitec Corp. 701A Acoustic Coupler	$ 300.00
TOTAL:	$7,100.00

The above terminal equipment could operate at either 10 or 30 characters per second.

The TSP plotter was modified so that the plotter output could be used for classroom projection. Figure 2 illustrates the resulting apparatus. The baseplate of the plotter was replaced and cut out to accept a Fresnel lens from a Model 88 3M Corporation overhead projector, thus enabling the plotter to operate both on graph paper in the usual fashion, or as a classroom projector if the plotting were made on acetate sheets using special water-based ink cartridges. The projection lens and lamp were carefully mounted and centered above the Fresnel lens as shown in Figure 2. When projection is not desired, a piece of paper is placed over the Fresnel lens. Table I lists the equipment used in the modification.

Cost Effectiveness of Group Display Techniques

If a multi-purpose terminal and plotter are used in the classroom, considerable cost reduction is achieved compared to individualized instructional use. Further cost reduction is possible by the off-line operation. Interactive sessions can be recorded and replayed to drive the terminal equipment. This technique is described under the section "What Happens When the Computer Goes Down."

Operating Costs

Operating costs for the graphics terminal consist primarily of computational charges and telephone line costs. Other cost factors such as paper, pens and supplies are negligible. The computer cost can best be described by

considering an hour of terminal operation either by a student or during a lecture in a classroom. Line costs at the University of Texas are fixed at 40¢/hour, which is considerably less than typical commercial rates ($10-$15/hour). Thus, the major operating expense is the computational cost, i.e., the amount of computing time actually expended during an hour of terminal operation, but this would not be true if commercial line costs were in effect.

Computation costs depend directly on the complexity of the calculations and, in the case of a dynamic simulation, the amount of process time simulated. Computing charges at the University of Texas are $260/(TM hour), where a TM(sec) is defined as:

$$\begin{aligned} \text{TM(sec)} = {} & \text{Central Processor(sec)} + \\ & (\text{disk I/O records}) + 0.004 \\ & + (\text{Tape I/O records}) + 0.048 \end{aligned}$$

For example, if an instructor or student simulated the dynamic behavior of a continuous-stirred-tank reactor with a residence time of 5 minutes for a period of one hour of process operation, the computation costs would be about 20¢; however, for the case of a tubular reactor which requires more computation, the cost for one hour of simulated process time is 93¢. Typically we have found that during an hour of interaction with simulation programs a student will use about $3.00 of computation time. If the line cost is added in, the total operating expense is $3.40/student hour. This same figure of $3.40/terminal hour can also be used as the basis for determining the classroom operating costs. A

distinct cost advantage of classroom operation is that the cost per student hour decreases in proportion to the number of students. Therefore the cost per student hour in a class of 34 is only 10¢/student hour.

Modification Costs

Since the group projection plotter is a prototype developed jointly by The University of Texas at Austin (Project C-BE) and Houston Instruments, Inc., the modification costs can only be estimated. The major cost items are listed in Table I and, in addition, some labor was required. We estimate that the parts plus labor cost will be under $300.00 for most organizations.

Maintenance and Repair Data

The requirements for maintenance and repair of the terminal, plotter and data set equipment are an important factor when the equipment must be used in a classroom either for individualized instruction or group instruction on a scheduled basis. The problem is minimal in large institutions that have in-house electronic technicians for support, or conversely if the equipment is located in large cities where commercial vendor repair support is available at a reasonable cost. In either case, budgetary costs are estimated to be between seven and ten percent of the acquisition cost of the equipment per year under the worst case situation. It is recommended in the case where no in-house repairmen are available that contract maintenance agreements be mandatory for any educational institution planning

to use this type of equipment. Also of primary importance is the use and orientation of proctor personnel to assure that the students do not abuse or improperly operate the equipment. Our own experience on maintenance has been that where scheduled (preventive) maintenance was performed (cleaning, oiling and minor adjustments), trouble calls diminished fifty percent. As a final note of caution, it is recommended that only properly trained or qualified repair personnel be allowed to repair the equipment since more harm than good can result from the "amateur fix it syndrome."

What Happens When the Computer Goes Down?

Though time-sharing services are generally reliable, at least for student and research uses, the introduction of plotted output of computer graphics in the classroom as a teaching tool places a new requirement of robustness on machine reliability. One way to partially resolve this problem has been to audio tape record the computer data signals generated during an actual on-line student simulation exercise on a conventional recorder. In this manner, much as teachers tape their lectures, we are able to tape the interactive program on a standard reel to reel recorder and use the recorded (ASCII coded) signals to drive the plotter. Thus, when the recording is played back through the data set of the terminal equipment, the effect is essentially the same as though the computer were actually operating on-line. By cataloguing the tape footage and through use of the digital counter positions on the recorder, the teacher can rapidly

access the various recorded demonstrations during a lecture to selectively illustrate concepts graphically to the entire class at one time.

Though this backup system lacks to some degree the flexibility provided by real-time computing, it does provide the effect of real-time graphics and reduces the need for perfect reliability on the part of the time-share system.

Conclusions

We have described our approach in using computers more efficiently in undergraduate classroom education. Specifically the discussion was focused on six areas:

(1) Interactive computing

(2) On-line graphics

(3) Group display of on-line graphics

(4) Equipment costs

(5) Operating costs

(6) Maintenance

Each of the six elements strongly influence the use and effectiveness of computers in education. We feel that interactive computing with on-line graphics provides an essential stimulus in conveying concepts and information to the students. Since costs are and have been a restraining force affecting the use of computers in classroom education, the judicious selection of equipment is important. At present the combination of a printer and X-Y plotter

provides a very good graphics terminal at a fraction of the cost of more elaborate equipment. By adding the projector to the plotter, significant cost reductions are possible as compared to individualized student use.

It is hoped that the information derived from this project will aid others in their development and application of computer-based education.

Acknowledgement

This research was supported in part by Project C-BE under Grant GY-9340, "The Use of Computer-Based Teaching Techniques in Undergraduate Science and Engineering Education" from the National Science Foundation to the University of Texas, Drs. John J. Allan and J. J. Lagowski, Co-Directors.

Acknowledgment is made to Houston Instrument Corporation for their technical engineering assistance in adapting the overhead projector to the plotter. Figure 2 was photographed by W. L. Lansdon, Houston, Texas.

TABLE I

EQUIPMENT USED FOR MODIFICATION OF TSP-212 PLOTTER/PROJECTOR

1. Project Head; part of Model 88 Desktop (Overhead) Projector; 3M Corporation, Minneapolis, Minnesota. Cost of Projector is $190.00.
2. 3M Transparency Slate for Model 88 Desktop Projector; Part #78-8704-4814-5. Price $11.50.
3. Acetate, Clear 11" x 17" sheet, .03 mil thickness; (1 package of 100 sheets) $20.00 H.A.I. Plastics Co., 3411 Kiest Blvd., Dallas, Texas.
4. Cartridge, Ink, Black (or Red); Graphics Control Corporation, Cherry Hill, New Jersey 08034 (made especially for Houston Instruments K-41, #186-9); 100 each, $2.00/cartridge minimum order.
5. Stainless steel sheet replacement for TSP-212 (top) plotter base. ($20.00)

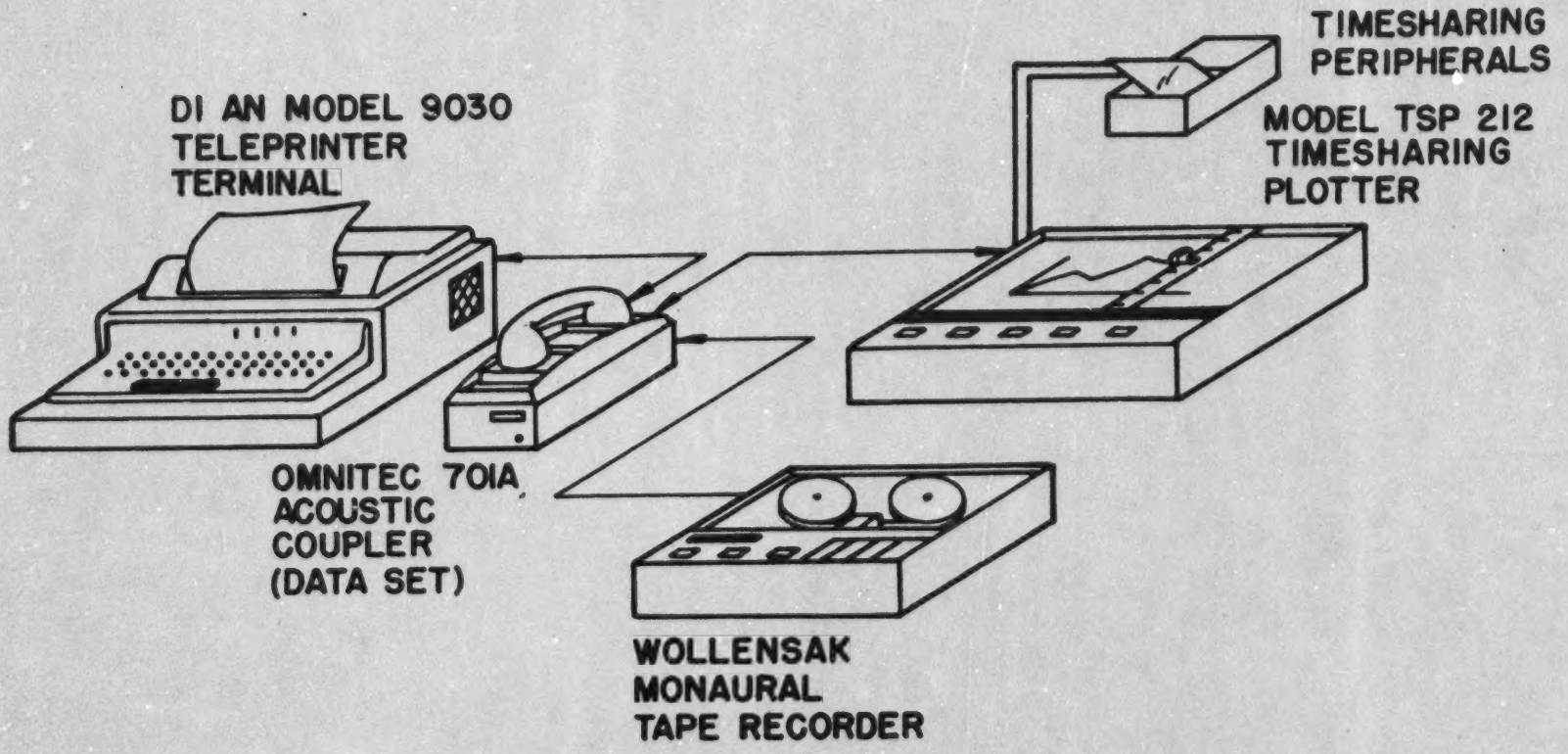
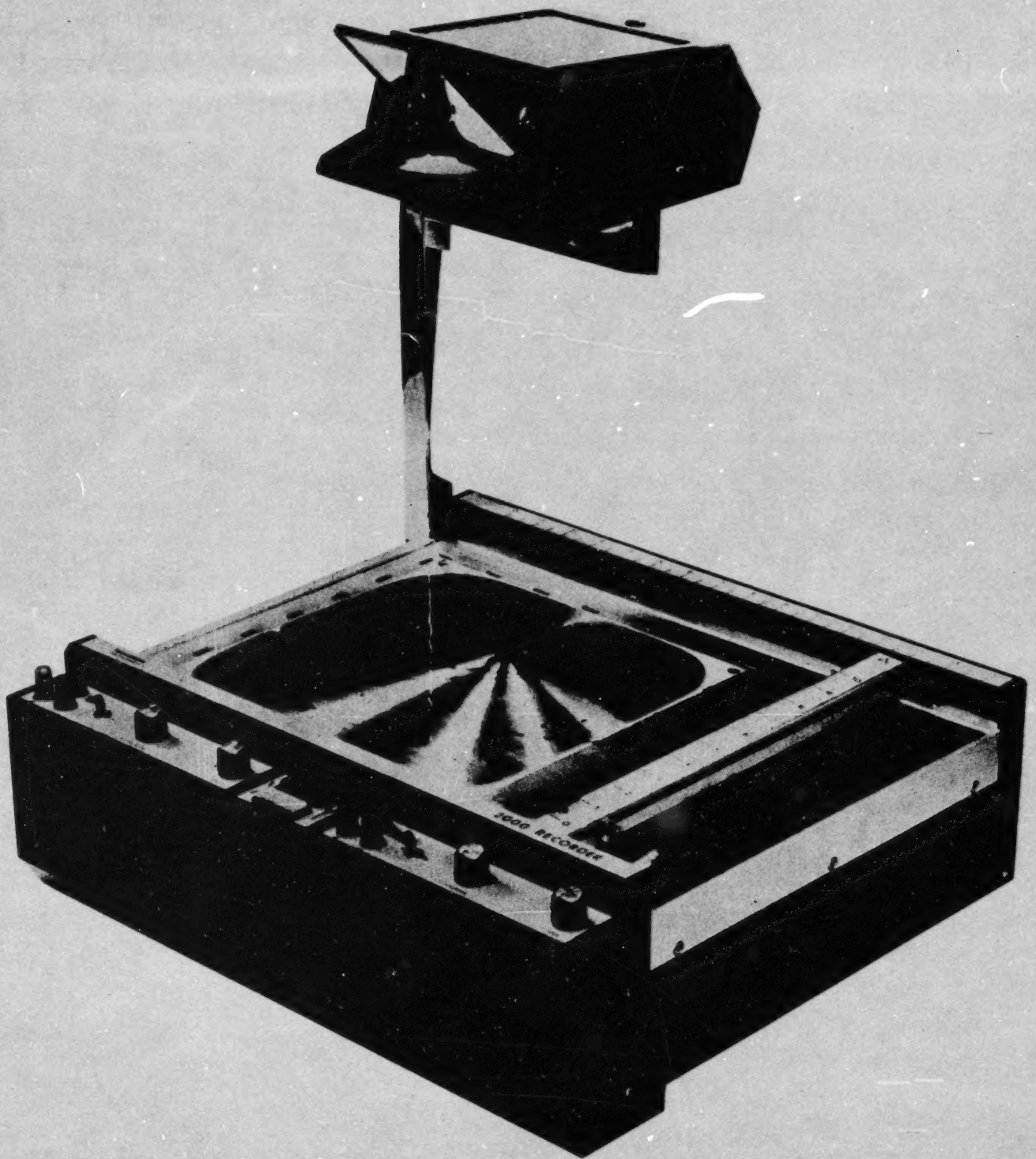


Figure 1. Equipment Used to Bring Time Share Computing into the Classroom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